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Impact of Data Assimilation on Cost-Accuracy Tradeoff in Multi-Fidelity Models at the Example of an Infiltration Problem

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Infiltration into top soil can be described by alternative models with different degrees of fidelity: Richards equation and the Green-Ampt model. These models typically contain uncertain parameters and forcings, rendering predictions of the state variables uncertain as well. Within the probabilistic framework, solutions of these models are given in terms of their probability density functions (PDFs) that, in the presence of data, can be treated as prior distributions.

The assimilation of soil moisture data into model predictions, e.g., via a Bayesian updating of solution PDFs, poses a question of model selection: Given a significant difference in computational cost, is a lower-fidelity model preferable to its higher-fidelity counter-part?

We investigate this question in the context of heterogeneous porous media, whose hydraulic properties are uncertain. While low-fidelity (reduced-complexity) models introduce a model error, their moderate computational cost makes it possible to generate more realizations, which reduces the (e.g., Monte Carlo) sampling or stochastic error. The ratio between these two errors determines the model with the smallest total error. We found assimilation of measurements of a quantity of interest (the soil moisture content, in our example) to decrease the model error, increasing the probability that the predictive accuracy of a reduced-complexity model does not fall below that of its higher-fidelity counterpart.